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SOME CONCLUSIONS DRAWN FROM A SURVEY OF SEWAGE TREATMENT PLANTS.[1]

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During the past 20 years many processes and devices for sewage treatment have been developed and actually demonstrated by being installed in various plants throughout the country. In many cases they have been abandoned by their real parents, the designing engineers, and apprenticed out to foster parents, who, while demanding maximum service, have cruelly neglected them. With this neglect, they have often failed to render proper service and have thereby come into disrepute.

THE SURVEY.

During the summer of 1920 the United States Public Health Service undertook a survey of 15 sewage treatment plants, located in 12 cities in different parts of the country, and considered to exemplify different processes and different conditions. The objects of this survey were : (1) To obtain a bird's-eye view of the field of sewage treatment; (2) to secure basic data by which the efficiency of service could be judged; (3) to suggest some standard tests which might, without undue labor, be adopted at all plants so that results at different plants would be comparable.

The plants selected for the survey were, therefore, those which were felt to be representative, receiving reasonably careful and intelligent operation. The devices and processes employed at these plants included primary plain sedimentation, septic, hydrolytic and Imhoff tanks; fine screens; trickling, contact, and intermittent filters; secondary sedimentation; and activated sludge. It was originally planned to study chemical precipitation and Dortmund tanks, but they were for various reasons omitted from the schedule. At no plant visited was routine disinfection practiced.

The collection of the basic data was divided between an engineer and a chemist. The engineer secured the details of the design and construction of the plant, the population and industrial plants contributing to the sewers, the sewerage system, and other factors bearing upon the operation of the plant. He also took up the opera-

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tion, and in some instances special subjects such as the use of sludge as a fertilizer or soil builder. The basis of this part of the survey was a 21-page questionnaire. Plans of the plants were secured for use in the preparation of the final report.

The chemist spent from 10 days to over two weeks at each plant analyzing an average of 12 series of 24-hour samples. These samples were composed of portions taken each hour before and after each phase of the treatment. They were stored on ice during the period of collection. Sufficient laboratory equipment to perform all the selected determinations was shipped from place to place by the chemist. This work was (at all except four plants) done by the same chemist, assuring identical methods and eliminating the personal equation in the comparison of results from any two plants. The analytical work at the four plants not visited by this chemist was done by men who had received very detailed instructions from him.

The analyses selected for routine on this survey were not those which would be recommended for a plant operator. It was desirable and possible to include some analyses which were considered to be of little value for operating purposes, such as the chlorides, and others which were of doubtful value, probably not giving sufficient information to justify the labor involved in making them. No nitrogen determinations, other than nitrates, were made at any except the activated sludge plants, where the ammoniacal nitrogen determination is of value in judging the efficiency of the aeration.

The following plants were surveyed: Two Imhoff tanks and trickling filter plants without secondary sedimentation at Atlanta, Ga., and one at Columbus, Ohio; a combination of plain sedimentation and Imhoff tanks followed by contact beds and final intermittent fine cinder or sand filters at Alliance, Ohio; Imhoff tanks with contact beds at Canton, Ohio (the last two having glass-covered sludge drying beds); hydrolytic tanks, fine screens, trickling filters, secondary sedimentation and sludge digestion tanks at Baltimore, Md.; Imhoff tanks, trickling filters and secondary sedimentation at Rochester, N. Y., Fitchburg, Mass., and Lexington, Ky.; septic tank, trickling filters and secondary sedimentation at Reading, Pa.; fine screens, Riensch-Wurl, followed by Imhoff tanks and disposal by dilution without oxidation at Rochester, N. Y.; and activated sludge at two plants at Houston, Tex., and at San Marcos, and Sherman, Tex.

Raw sewage.—Except at plants treating sewage from separate sewerage systems, the total flow was not ascertainable, because of the wastage by overflows or by-passes, which are used when the flow exceeds the maximum capacity of the treatment plant. The volume passing through the treatment plant was known fairly accurately at

all but the two smallest plants, where the flow averaged, as actually measured on the survey, less than a half million gallons daily.

The per capita volume treated averaged very close to the commonly used figure of 100 gallons per day, it being about 94. There were 9 with smaller and 6 with larger flows. Six were within 10 per cent of the average, five within 25 per cent, and four from 36 to 58 per cent.

The number of people served per sewer connection averaged 5.4, with variations from 3.8 to 7.1. The number of connections was not known at four places.

The character of the sewage received at the different plants varied, as would be expected, within wide limits. Suspended matter ranged from 101 to 297 parts per million, averaging 174. Except at plants where an unusual amount of industrial wastes is discharged into the sewers, as at Gloversville, N. Y., it is not probable that many municipal sewages are more concentrated than some of those studied, and sewages with less than 101 parts per million of suspended matter are seldom encountered. It is believed, therefore, that the survey included a good cross section of American sewages.

Solids settleable in two hours in Imhoff glasses ranged from 1.9 to 4.9 c. c. The values obtained from this determination do not correspond very closely with the suspended matter obtained by the Gooch crucible. Readings of 4.8 and 4.9 c. c. were obtained with sewages containing 261 and 264 parts per million of suspended matter, whereas only 2.7 c. c. were settled from the sewage containing 297 parts per million, and 2.0 c. c. from the least concentrated sewage containing 101 parts per million, and also from two other sewages containing as high as 226 parts per million.

The oxygen-consumed values, by the 30 minutes in boiling water method, ranged from 24 to 69 parts per million, averaging 44.

The 5-day biochemical oxygen demand averaged 114 parts per million, the maximum value being 190 and the minimum 67.

Imhoff tanks.—While Imhoff tanks were in use at 10 out of the 15 plants, at two plants the effluent from the Imhoff tanks was mixed with that from other types of tanks with which they operated in parallel, and the samples analyzed were the mixed effluents. On the whole, the Imhoff tanks performed their function of removing suspended matter very satisfactorily, the average removal amounting to 59 per cent. At only two plants was it below 60. These being 37 and 40, pulled down the average. Accompanying this the biochemical oxygen demand was reduced 42.5 per cent, and the permanganate oxygen consumed 36 per cent. The last two figures are rather interesting in that the reduction of the 5-day oxygen demand was greater than that of the oxygen consumed. Studies of industrial wastes by the United States Public Health Service at Cincinnati,

Ohio, have indicated that the removal of solids affected the oxygen consumed to a much greater degree than the oxygen demand.

As affecting subsequent treatment, the actual amount of suspended matter in the tank effluent is of more importance than the per cent removed by the tanks. The Imhoff tank effluents at half the plants contained between 60 and 70 parts per million; three contained more, the highest being 119, and one contained only 40. The effluent containing 119 parts per million received no subsequent treatment. Detention periods for normal flows averaged about four hours, computed on a total displacement basis, and, with this detention period, the velocity averaged about 0.6 foot per minute.

Foaming appeared to be more of an occasional nuisance than a serious difficulty of operation. With but one or two exceptions, most of the tanks foamed at one time or another, but relief could be obtained by the withdrawal of sludge. This method was accepted by all the plant operators as the only one capable of giving permanent relief.

The capacity of the digestion chambers, below the overlap of the slot, averaged for all 12 installations 1.3 cubic feet per capita served; but omitting two plants at which this factor was purposely made unusually large, both being 2¼ to 2½, the average for the remaining 10 plants was 1.1.

Considering the variations in the character of the sewages entering the tanks at different places, and the differences in the many design factors, it is not possible to compare the efficiencies of tanks at different plants on the basis of any selected design factor. In a general way, it seems that refinements in minor features do not materially affect operation.

Trickling filters.—Trickling filters were studied at eight plants. At six they were preceded by Imhoff tanks; at one by hydrolytic tanks, with a small admixture from Imhoff tanks; and at one by a septic tank. The depth of the filters ranged from 5 to 10 feet; but at six of the eight plants the variation was from 5 to 6 feet.

The rates of filtration fell for an equal number of plants above and below 2 m. g. d.; but at two of the four plants operating in excess of this rate, there was sufficient filter area available to effect rates below 2 m. g. d., if it was all used regularly.

The physical appearance of the effluents was good at all except one plant, and this plant was the only one at which there was any appreciable pooling, though the surface layers of several others exhibited considerable clogging. When it is remembered that some of these filters have been in continuous operation for 10 to 12 years with very little expense other than occasionally going over the surface with a pick or harrow or flushing with a hose, there appears to be little reason to anticipate any material decrease in efficiency.

The analytical results obtained from all the effluents, with the exception of those from the pooling filter, were good. One of the most interesting results obtained from the studies of these plants was the uniformity of the final effluents. The raw sewages pretty well covered the range of concentration of American sewages. Preliminary settling, however, in tanks of totally different design and operation produced effluents of remarkably similar character, and the trickling filter effluents were all of such like composition that they could well be expected to have come from the same filter in a period covered by the survey as a whole.

Suspended matter determinations may be misleading or meaningless for trickling filter effluents, as this constituent varies so greatly with the cycle of operation of the filter, from the storing period to the unloading period. The character of the solids in the filter effluent is, moreover, totally different from that in the influent.

The filter is an oxidizing device and its efficiency must, therefore, be judged by determinations involving the presence of oxygen. Three such determinations were made: The oxygen consumed, the oxygen demand, and nitrogen as nitrates. This last determination is of relatively little value unless the amount of nitrogen in other forms present in the influent is known. Low nitrates in themselves mean very little.

Omitting the one clogged filter already mentioned, the oxygen-consumed values for the plants studied fell within the relatively narrow limits of 7 and 19, and the 5-day oxygen demand values between 4 and 20. The one pooled filter had an oxygen-consumed value more than twice the average of the other filters, and a 5-day oxygen demand about two and one-half times as great as the maximum value for the other filters.

Another interesting fact brought out by the analytical work was the reduction of the methyl orange alkalinity by the filters. At all except one plant this reduction amounted to over 30 per cent, and at one plant it was 92 per cent—from 99 to 8 parts per million. We could not undertake to obtain sufficient analytical data to definitely assign any reason for this reduction, but it may possibly be due to the use of CO_2 by bacterial activities in the filters which, when taken from the soluble bicarbonates in the influent, reduces these to insoluble carbonates, which are retained in the filter. This same reduction in alkalinity was found in all properly operating oxidizing devices, such as contact beds and aeration tanks of the activated sludge process.

Contact beds.—Contact beds were studied at Alliance and Canton, Ohio. While they did not produce results equal to the average of the trickling filters, the effluents were entirely satisfactory for ulti-

mate disposal with the dilution factors available. The oxygen-consumed values were 11 and 18, and the 5-day demand values 20 and 37, respectively, for Alliance and Canton. At neither place are these filters operated during the winter months.

Fine screens.—Fine screens were found at Rochester, N. Y., and Baltimore, Md. At Rochester, Riensch-Wurl screens precede Imhoff tanks and serve to keep large floating solids from the surface of the tanks and of Lake Ontario into which the Imhoff tank effluent is discharged. At Baltimore, rotating drum screens, similar to the Weand segregator, follow the tanks and serve to remove solids likely to clog the trickling filter nozzles. Their efficiency is best represented by a reduction of about 87 per cent in nozzles cleaned after the installation of the screens.

The analytical methods used in the survey failed to show any accomplishment by the screens at Rochester during the period of the survey. Suspended and settleable solids and oxygen consumed were slightly higher in the effluent than the influent, and the oxygen demand was slightly lower; but in none of the determinations was the difference of any significance. Computing from the screenings collected back to equivalent solids, the removal amounted to less than 1 or 2 per cent.

Activated sludge.—Four activated sludge plants were studied at three Texas cities. At Houston are the two largest plants in actual permanent operation in this country. At San Marcos is the reputed first municipal plant of this type; it is of very small capacity, as is also the plant at Sherman. The smallness of these plants makes them worthy of study, in view of the stated opinions of some engineers that this process is adapted only to large installations, where highly paid operators are in charge and where there is sufficient sludge to warrant its profitable recovery.

The San Marcos plant, treating less than 200,000 gallons per day, was the smallest plant studied. In actual man-hours it received much less attention than any of the other plants, with the possible exception of the Sherman plant. A good general utility man visited the plant every day to oil the machinery and make a brief general inspection. The influent was a weak domestic sewage, and it was passed through a septic tank before entering the aeration tank. The effluent ranked well among the best of those studied, with a suspended matter content of about 3 parts per million, an oxygen-consumed content of about 8, and a 5-day oxygen demand of 16, with ample contained oxygen in the form of dissolved oxygen and nitrates to more than satisfy this demand.

The cost of operation per million gallons naturally was high, amounting to about $20, including interest on the money invested. This is equivalent to an annual cost of $1,400, or about 56 cents per

capita served, which, considering the contributing population of 2,500, does not appear excessive.

This plant may be taken to illustrate the adaptability of the activated sludge process to small installations, and it brings up the question of the value of presettling the sewage before aeration in such installations, where the recovery of the commercial value of the sludge is not feasible.

The value of the activated sludge process for small installations may also be considered from another angle. It obviously is not entirely automatic. I feel that too much emphasis has been placed on the so-called automatic operation of other types of sewage treatment devices. Many, one might almost say most, small sewage plants have been installed with the idea firmly rooted in the minds of the city officials that the plants will run themselves. Certainly it must be admitted that the officials' actions bespeak such convictions. It seems that there might be a distinct inherent advantage in a process which must require some attention to operation. Motors and blowers or air compressors can not run day after day without oil at least. Moving machinery must be cared for. To insure a daily visit to the plant is of real value.

It appears possible that the activated sludge process may find its greatest field of usefulness in small installations rather than, as is at present held, in the large ones. In small installations, and especially with presedimentation, the sludge problem is greatly reduced, whereas with large installations, present opinions predicate its economic feasibility upon the commercial value of the sludge produced and the cost of its reduction to a commercial form.

The plant at Sherman, Tex., did not present as optimistic a picture as the one at San Marcos. The effluent was comparable with that from the already mentioned pooling trickling filter. The sewage was extremely concentrated, receiving night soil from a population about equivalent to that connected to the sewers, and this night soil was dumped into the sewers so close to the treatment plant that it reached the plant in an almost unbroken condition. The installation of a preliminary settling tank might greatly facilitate the operation of the aeration tank; but even then better operation would be essential to produce a uniformly first-class effluent.

Both of the two large plants at Houston produce excellent effluents. There is no longer any doubt of the capability of the process to effect adequate treatment. The problem at Houston, as at all large plants of this type, is the ultimate disposal of the sludge produced. There are great possibilities and promise of ultimate solution of this problem, but so far no sludge-handling plant has operated sufficiently to demonstrate either success or failure. No new data on this subject could be secured during the survey. The attitude

of most engineers still remains a mixture of anticipation, hope, and doubt.

Utilization of sludge.—Utilization of sewage sludge usually carries the idea of some ambitious scheme for the preparation of a market fertilizer from the sludge which will result in large financial returns. Sludge for the most part takes the extremes (*a*) of being no earthly good, a valueless waste, a liability to dispose of; or (*b*) of being possessed of so much value that it must pay not only for its own disposal but also for a portion of the cost of the treatment of the sewage. The saving of the expense of hauling the sludge from the plant to a dump and any small revenue for its sale have in most places not been considered worth the trouble of creating a local demand.

At three of the plants visited—Alliance and Canton, Ohio, and Rochester, N. Y.—the sludge is all used by local farmers. At the time of the survey Rochester was the only place where any charge was made for the sludge, but at the other two places the growing demand will probably eventually give to the sludge a commercial value.

The psychology of disposal to local farmers has recently been well expressed by Mr. N. A. Brown, of Rochester, when he said that as long as sewage-treatment officials themselves tell the farmers that the sludge has little if any fertilizing value, the farmers will not be inclined to haul it away, but that if the farmers see that the officials think it worth selling, they will not only haul it away but will pay a price for it.

The average farmer is practical when it comes to hauling fertilizer. If he does not get any benefit, he stops using it. And yet at the three plants visited and also at Lexington, Ky., farmers are calling for the sludge year after year, and taking ever-increasing amounts.

A sewage-plant operator objected to my use of the word "sludge" as "fertilizer" when referring to the value of sludge to growing crops. To him fertilizer meant the three plant foods—nitrogen, phosphates, and potash—and the value of sludge had to be judged by its content of these ingredients, and by them alone. This is a common attitude, which I feel is the wrong one to take. It is well recognized that manures, horse litter, and barnyard compost produce greater results than can be expected from their nitrogen, phosphates, and potash constituents as determined by analysis. For total content of these three plant foods, sludge can compare very favorably with manures. Both form humus and build soil by improving its texture.

Some experimental work has been done to test the value of sludges by their actual effect on growing vegetation; but I can not feel that any have been extensive enough, on a large enough scale, or with proper control to justify the prevailing low opinion in which sewage

sludges are held. The American Society of Municipal Improvements and other organizations have by resolution called upon the Department of Agriculture to conduct actual large scale tests. If such tests are made, it is to be hoped that a part of them will be run with sludge as sludge and not solely as a vector for the three plant foods. The survey of the sewage-treatment plants has made me believe that the whole value of sludge can not be stated in the analyses of nitrogen, phosphates, and potash.

One need not be an expert in farming to form an estimate of the benefit of sludge to grasses, wheat, oats, and other crops at Canton, Ohio. It is written in the fields so that he who runs may read. Unfortunately, none of the results obtained by the farmers can be converted into quantitatively controlled figures. One farmer stated that by actual weight he obtained with two cuttings 34 tons of grass from 9 acres treated with sludge in a 49-acre field, while from the other 40 acres he had only one cutting, which totaled 42 tons. Whether there were other explanatory factors is not known; but this farmer considers sludge superior to barnyard manure and is each year hauling all he can.

It must be admitted that such reports are not in keeping with experience at some other places, and in themselves do not definitely prove anything; but they are worthy of consideration. They evidence the need for a more complete and more thorough study of the whole question than has as yet been made and indicate the advisability of placing just a little less emphasis on chemical analyses in rating the value of sludge as a fertilizer.

I do not want to give the impression that I consider sewage sludges market competitors of commercial fertilizers. But I do believe that at most sewage treatment plants a local demand for the sludge can be created on an actual value basis which will not only be the means of the ultimate disposal of the sludge but will produce a revenue which will, at least partially, pay for the cost of handling the sludge after its removal from the tanks.

There are three possible causes for failures of sewage treatment plants: (1) The processes may not in themselves be capable of producing a good effluent; (2) the design of the individual plant may be at fault—capacities of the devices inadequate to handle the load placed upon them; and (3) poor operation or, as is often the case, no operation at all.

The first of these presents the most serious aspect. Opinions have been expressed, even among those familiar with sewage treatment, that the whole system and theory of sewage treatment practices has fallen down. This feeling has gained some ground among the uninformed who have come into contact with conspicuous failures of plants supposedly of the best design and supposedly entirely automatic.

The second cause of failure is restricted to individual plants and can be largely eliminated when the public and especially city officials thoroughly understand that the designing of treatment plants is a specialized branch of professional engineering and that such plants are not a part of the city's plumbing system.

Finally, failures due to poor or to no supervision of operation will gradually be reduced by education and expensive experience.

This 1920 survey by the Public Health Service was primarily concerned with the first and most serious alleged cause of failure. For this reason the plants selected for study were those which were considered to have been properly designed by engineers versed in the principles involved and which were receiving good or at least reasonable attention and operation.

It was originally planned to continue the studies in subsequent years, specializing in plants where design was at fault and where supervision of operation was obviously below a required minimum. It was also intended to study the adaptability and efficiency of the different principles of treatment at smaller installations than those studied in 1920. These studies have, however, been at least temporarily abandoned.

REVIEW OF RESULTS OF THE SURVEY.

In reviewing the results of the survey as a whole, there does not appear to be much ground for pessimistic criticisms of general theories of sewage treatment on the basis of their failure to effect adequate purification. All municipal sewage must ultimately be disposed of by dilution in some body of water, and the purpose of treatment is to prepare the sewage so that it will not produce objectionable conditions in the receiving body of water or, in some cases, place an undue load on a water purification plant using the receiving body of water as a source of supply. To these may be added the protection of bathing beaches, oyster beds, etc.

The primary function of preparing sewage for disposal by dilution without creating objectionable conditions was the main objective of the plants studied. No bacteriological analyses were attempted.

With but one or two exceptions, physical observations and analytical results agree that the plants visited were accomplishing the main object of their existence. All plants were seen during the warm months, the critical period of the year. At only 2 out of the 14 operating oxidizing devices was the color reduced in the methylene blue putrescibility tests of the effluents, which were incubated at room temperature. At one of these two the samples stood up for three to eight days. Only four of them had biochemical 5-day oxygen demands in excess of 20, and all had contained oxygen to partially satisfy this demand. With any reasonable dilution factor

no objectionable conditions should be created with the effluents from the oxidizing devices studied. In addition to oxidation, the treatment processes removed practically all of the settleable solids.

I do not argue that present-day practices represent the last word in sewage treatment. New methods, it is to be hoped, will be developed—better methods than any we have at the present time. Those existing now are not perfect, but they are not deserving of the unfavorable reputation they hold in the opinion of those partially informed and of limited experience. This reputation is based on ignorance and the reaction of disappointment over the failure of plants to accomplish results which have been extravagantly and improperly promised by promoters and, unfortunately, in some instances by engineers.

It is unfortunate that few if any plant operators have time or facilities to undertake original work or carry on special investigations. Conditions as a whole are such that the field of sewage plant operation offers but little attraction as a life work. The aim of the ambitious plant operator is to become a designing engineer. The studies of the basic principles of sewage treatment have been, to a very large extent, made at testing stations built and operated for the particular needs of individual cities. Relatively few of these have been in the hands of men who had previously been in the operating field, and from them have been developed only a very limited number of men who remained for any length of time in the strictly operating field. There have been few operators capable of or interested in such temporary specialized work, and the men who have been fitted have not seen an attractive future in plant operation.

The engineers of but relatively few of the plants in this country have had opportunity to study intimately the operation of the plants which they have designed.

There is need for a closer connection between these two phases of the subject. There is need also for the development of a group of plant operators to whom must be given sufficient inducements to retain them in this field. Compare the number of capable trained sewage-plant operators with the number of equally skilled men in the field of water filtration operation. Sewage treatment, unfortunately, has been the stepchild of municipal activities.

The time of a plant operator is always filled, with plenty of work left over. It is vital, therefore, that his activities be confined to those essential to the proper operation of his plant. This requirement applies to the laboratory work as well as to any other work at the plant. Each routine analysis that the operator makes should be selected to give some definite information on the condition in the plant, and on the efficiency of operation of the various devices Where several determinations give the same general information,

that one should be selected which gives it most accurately and with the least work.

The two functions of sewage treatment are the reduction of solids and the partial oxidation of the organic matter not removed with the solids. To these may be added, in isolated cases, the reduction of bacteria for the protection of a near water supply or bathing beaches, etc. In some cases the reduction of solids or of bacteria may be sufficient in itself, but the average plant is built for the first two objectives. The analytical determinations made should be selected, therefore, to tell the extent to which these two objectives are attained. The best determination we have to indicate the extent of the removal of solids is the suspended matter determination by the Gooch crucible. This determination on the influent and the effluent of the settling devices both primary and secondary, gives the data covering the main function of these tanks. The determination of settleable solids is much simpler and is advocated by some as giving the more nearly attainable efficiencies; but there appear to be uncontrollable factors and conditions in this method which limit, to a greater extent than the Gooch crucible method, its general application.

In the opinion of the men engaged on this survey, the best criterion by which to judge the efficiency of oxidizing devices is the oxygen demand by the excess oxygen method, stated in terms of the 5-day biochemical oxygen demand at 20° C. This method is possibly more elaborate and involves more technique than some of the other methods used to determine the biochemical oxygen demand, or than the oxygen consumed determination, but it has appeared to give the most enlightening and valuable information.

These two determinations can constitute the backbone of the laboratory routine of the average plant. With special methods of treatment, other determinations should be included as routine procedure, as, for instance, the ammoniacal nitrogen determination gives a most rapid method for control of the aeration processes at activated sludge plants. Of course, when bacterial removal is a function of the plant, total bacterial counts are essential for the proper operation of the disinfecting process.

It must not be inferred that the adoption of an irreducible minimum routine of laboratory work for all plants is advisable. Where facilities and time are available, other determinations should be added to the skeleton suggested. But there now exist at many laboratories elaborate routines containing the more tedious determinations, which give, when completed, very little information or data of use in the actual operation of the plant. These are extravagant users of the time of the plant operator—time which can be made to yield greater returns if devoted to other lines of activity.

Laboratory procedure at sewage plants has in a way, like Topsy, "just growed." Probably there are not two plants in the country, unless operated by the same man, where the schedule of analyses and the technique in making them are the same. Throughout the survey of 1920, our laboratory procedure was the same at all plants. At all except 2 out of the 15 plants, or 10 out of the 12 cities, some laboratory work was done regularly by local chemists. Our results, however, are, with the exception of the Gooch suspended matter and the Imhoff glass settleable solids determinations, not directly comparable with results obtained at any plant visited. Nor are the local results of any two plants directly comparable except in the two determinations mentioned. It is only by computation with average relation factors between two determinations or methods that any comparison of the functioning of the oxidizing devices is possible.

It is only natural that there should be a great reluctance at any laboratory to change methods, many of which may have been used for years and only by means of which can the results of future years of operation be compared with the past. Standardization can not come overnight, and should not be precipitately adopted. However, it is believed that the time is ripe to approach this subject with a little more assurance, to make definite selections of some one method of making different determinations, and to establish tentative schedules of routine from the irreducible minimum to those more elaborate at plants which are able to support them without sacrificing the physical operation of the plant. It is hoped that this survey may be a step in that direction, by furnishing comparative data covering a wide range of plants and a rather elaborate schedule of laboratory routine.

The future development of sewage treatment has need of more study than has been given in the past to the basic principles involved. Practical application has been made of phenomena which have, in many cases, been developed from experiments while their fundamental principles are only roughly understood. Their study in the light of the combined knowledge of the engineer, chemist, biologist, plant operator, plankton expert, and others will place the principles of sewage treatment on a firmer basis. Development does not necessarily mean the discovery of new unused principles; it includes the better understanding of principles already in use; for with this fuller knowledge will come more intelligent application of these principles.

Such investigations must include studies of conditions in the existing operating plants at which the theories of the laboratory must be given practical application. Surveys similar to this one made by the Public Health Service must be made to include more plants and more detailed study extending over longer periods of operation.

New problems and new ideas are continually coming to the front. Many of these can best be studied at existing plants where opportunities for study on a large scale are available. But others requiring special equipment and specialized laboratory work will probably demand study at testing stations. Industrial wastes, for example, require experimental work to be done at the point of origin.

For testing-station studies of domestic sewage, it would appear to be ideal to establish a permanent station, at which fairly large-sized units could be operated over long periods. The results of the 1920 survey indicate that the variation in raw domestic sewages at different places, where not complicated with industrial wastes of unusual quantity or character, is not a serious objection to restricting experimental work to the sewage of one locality.

At such a testing station new processes and devices, some of which are brought forward as commercial ventures with little authoritative data upon which to base any judgment of their value, could be subjected to at least preliminary tests—sufficient to eliminate those processes and devices the merits of which lie primarily in sales literature, based upon ignorance and imagination.

Such far-reaching and complete investigations of the scope suggested can not be undertaken by any one municipality, State, or section of the country. It must be national. The special studies at the central permanent laboratory and testing station must be fathered and supported by some national organization.

Around this organization should lie other cooperative bodies: First, a consulting board with experts specialized in different work, e. g., the various branches of chemistry, engineering, biology, sewage plant operation, etc., and second, a group of collaborators, including the engineering department of the State boards of health, universities, individual sewage plant operators, and other organizations or individuals.

Such a plan is not impossible. It has, in one form or another, been in the minds of and at times expressed and seriously discussed by men high in the ranks of the scientists versed in sewage treatment.

Investigations by such an organization would throw the light of definite knowledge over much of the present twilight zone of sewage treatment. They may not result in the discovery of any new short-cut processes—sewage may still remain a public liability—but we may expect them to effect appreciable economies in the treatment and disposal of sewage, to materially raise the standard of operation of treatment plants, and to protect the rivers, lakes, and other waters of the country from their improper use as diluents.